Opportunities in the Mechanical Parts of the System

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DARPA/MTO

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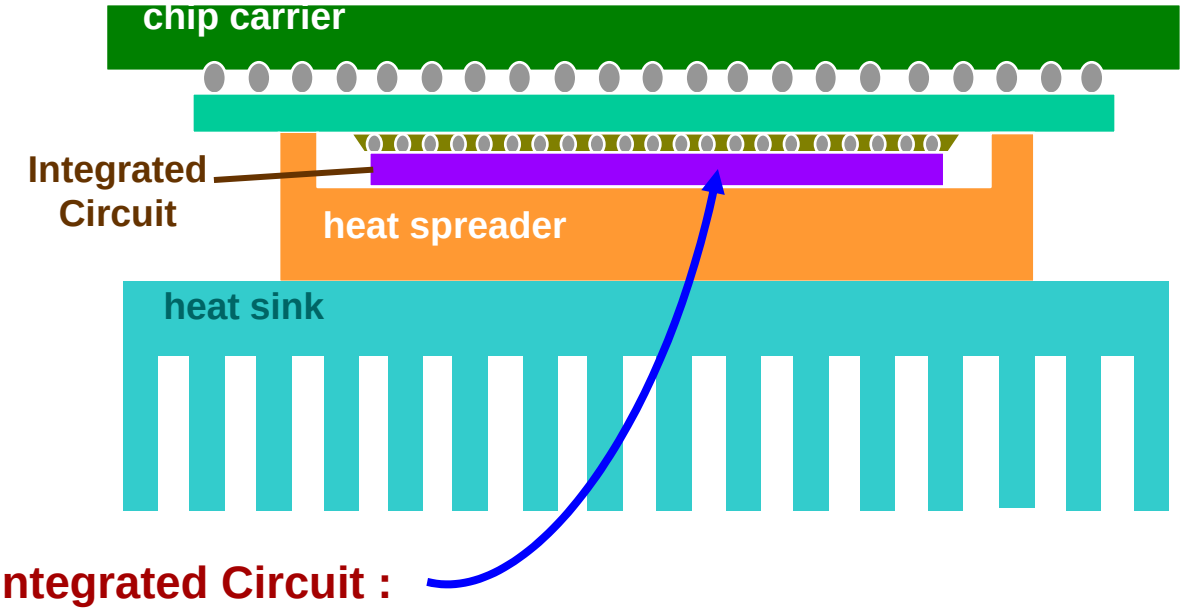

- 40+years of innovation in Materials, Designs, Architectures, Interfaces, Manufacturing…
- Mankind's Most Advanced Technological Achievement
- Beneficiary of many DARPA investments over the years

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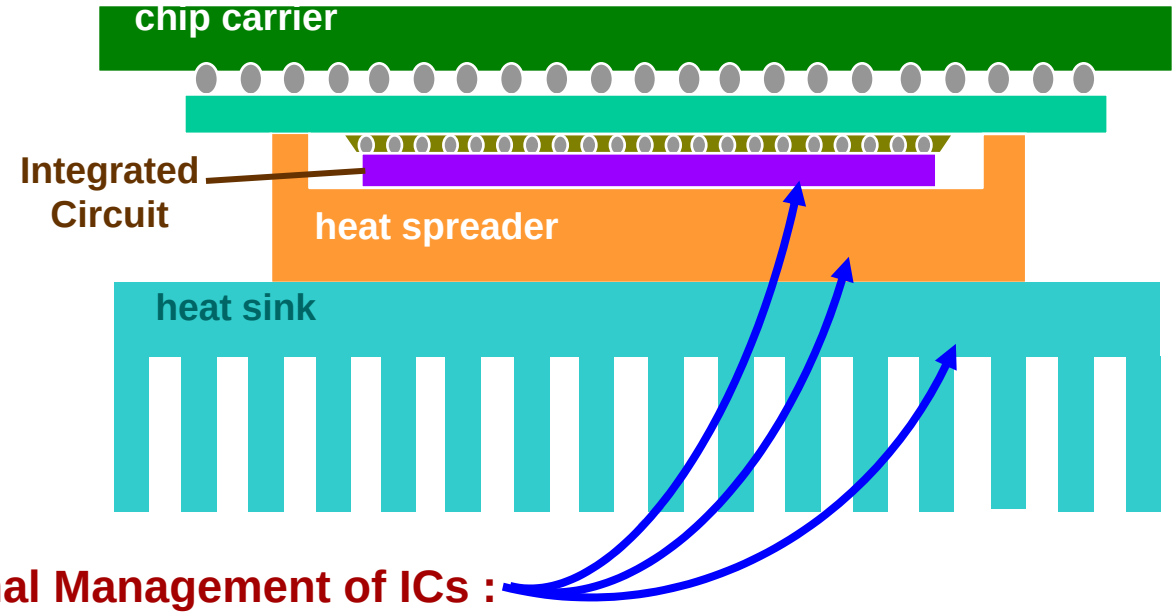

Thermal Management of ICs :

- **Materials set includes Grease, Copper, Aluminum**
- **Relatively few insertions of modern technology**
- **Few investments by DARPA**
- **Size, Weight, Cost, Performance of Thermal Management Technology is becoming a significant factor in Systems**

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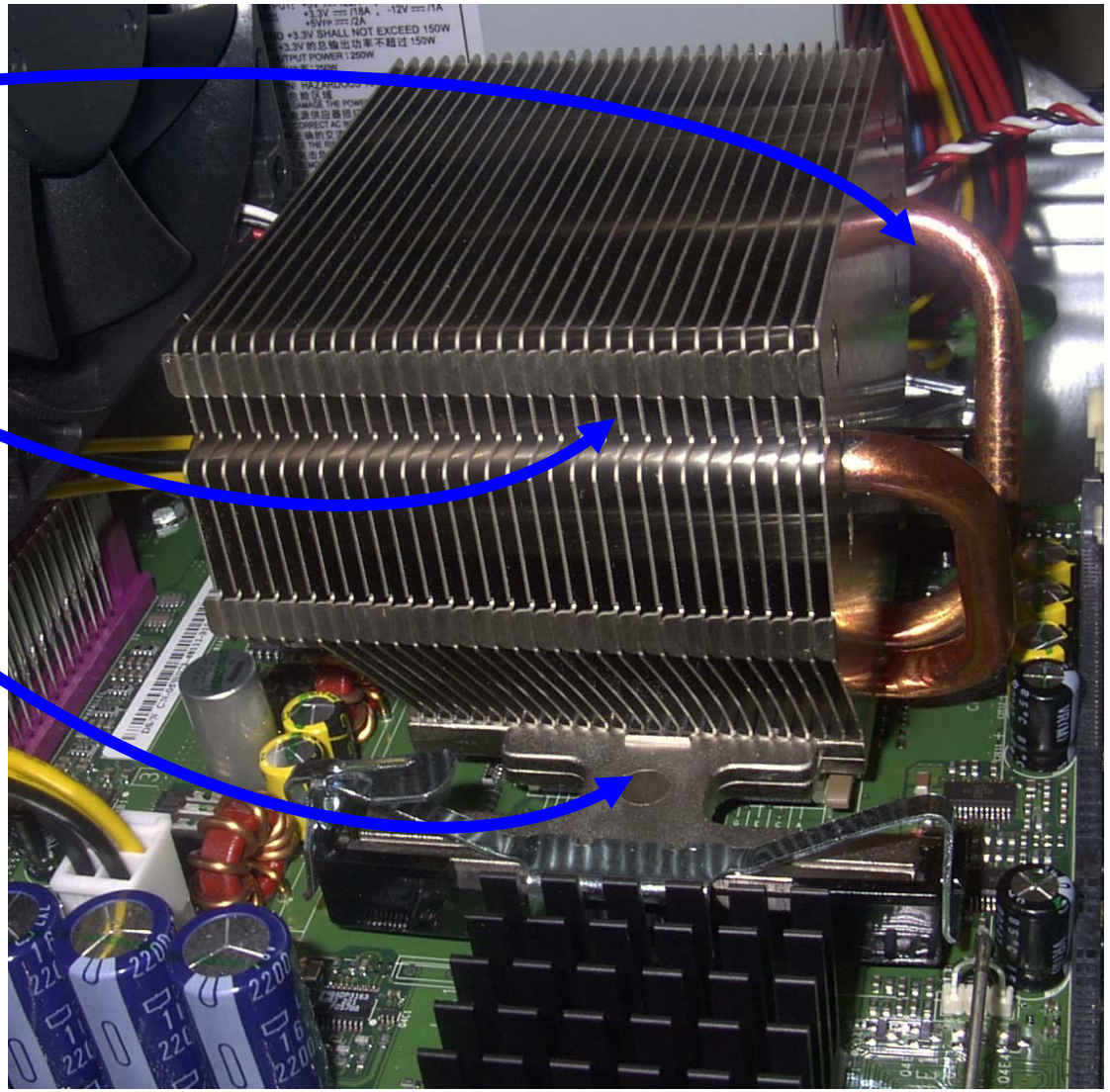
Heat Pipes woven through base and fins to provide efficient heat transport to full area

4”x4”x3”, 400 gm heatsink for thermal management of 90W Intel Microprocessor

Spring-Loaded Clamps for constant pressure on back of die, and minimize torque on interconnect



Size, weight, performance, reliability of thermal management can dominate DOD systems.

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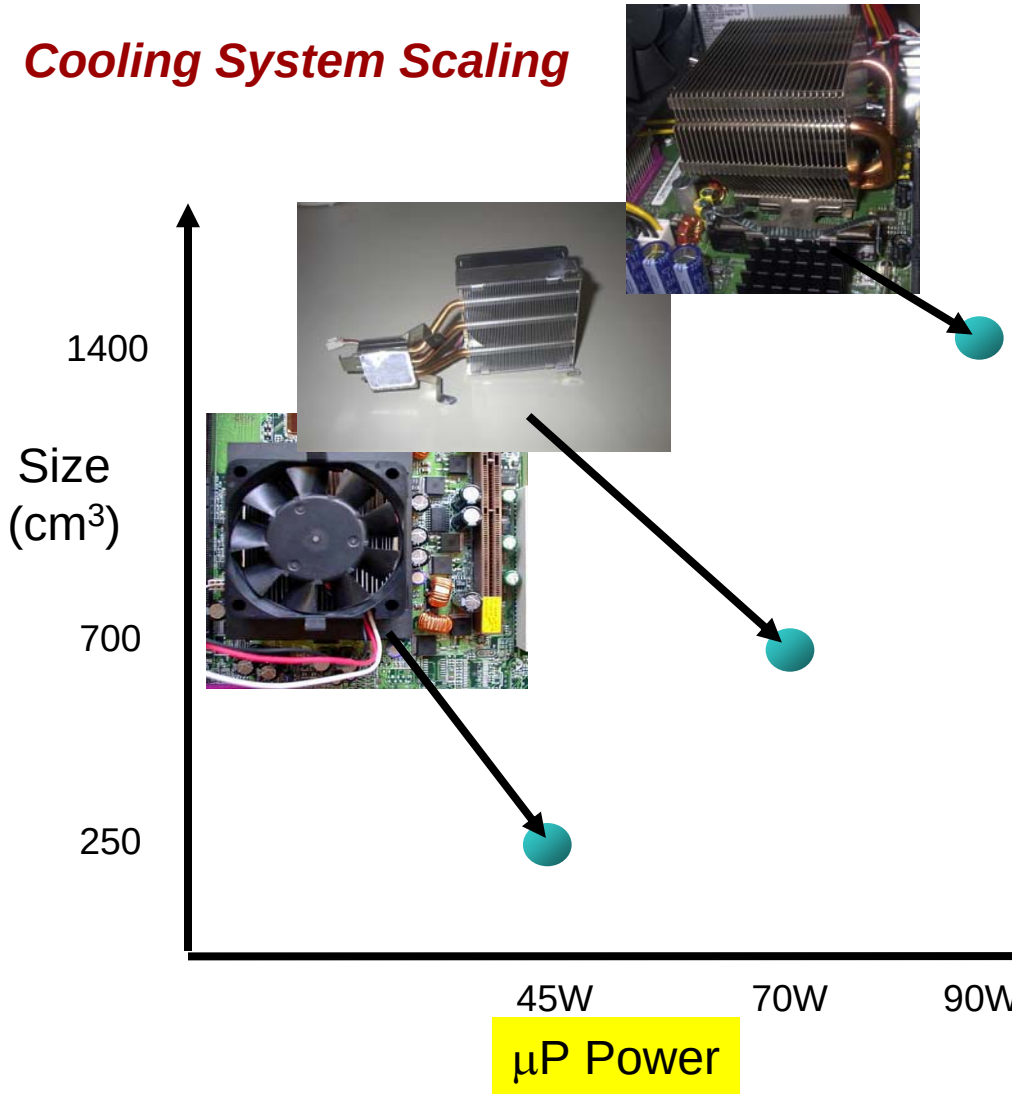
Cooling System Scaling



Scaling driven by :

- Increases in power density
- Thermal transport through grease
- Wicking/transport in heat pipes
- Fin thermal conduction
- Convective Heat transfer to air

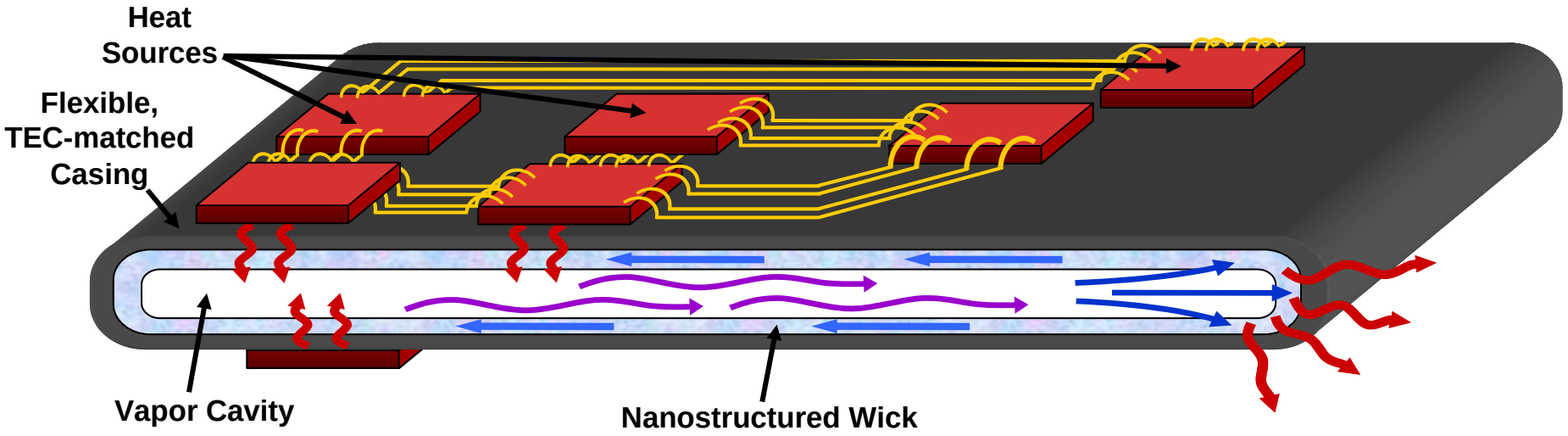
Recent industry transition to multicore is a "surrender" to this thermal barrier.

DOD systems suffer from same scaling. Cooling of computers, radar arrays, optics, instruments, engines - all limited by 50 year-old cooling technology.

It is time to bring high-technology, modern materials, nano-engineered interfaces, and adaptive structures to this problem. Possible benefits throughout DOD.

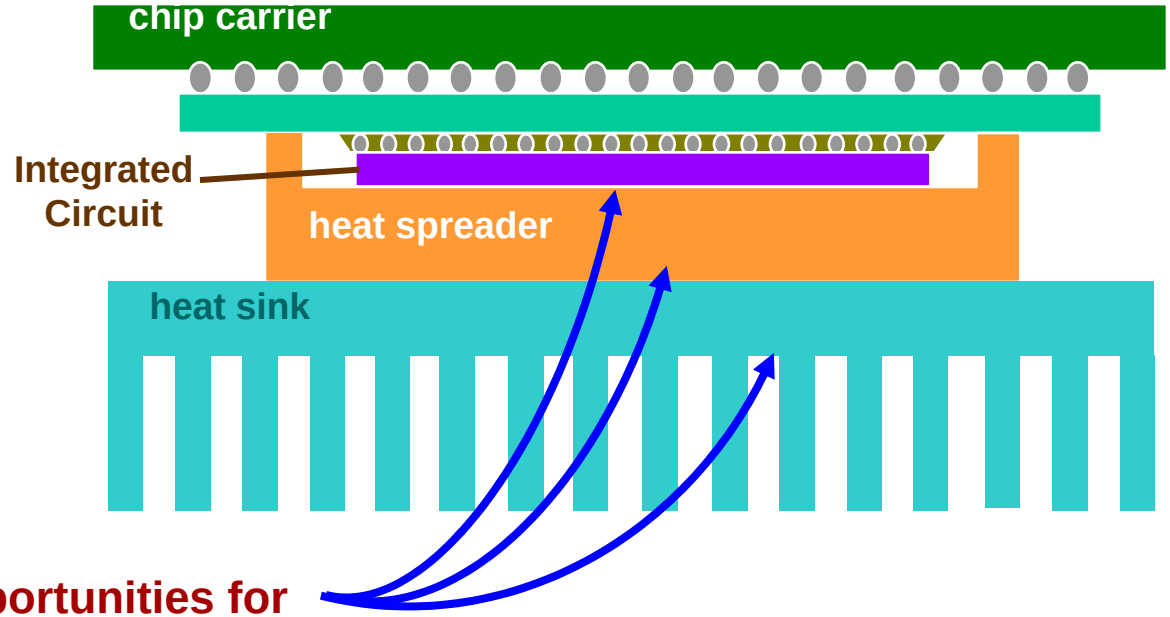
Example Opportunity

Technology Vision : **A new 2-D, thin, lightweight MCM substrate incorporating fluids, and nanostructured materials to achieve vastly superior thermal conduction & possessing all mechanical properties necessary for hard-mounting ICs.**



- Extreme lateral thermal conduction, 100X above current MCM substrates, capable of up to 1000X above Diamond
- Large 2-D area, <1 mm thick
- Nanostructured wick for enhanced heat transfer and fluid transport
- Structural, flexible, thin, & light-weight materials that match the TEC of Si, GaAs, or GaN
- 2-phase heat transfer to eliminate load-driven thermal non-uniformity across substrate

Other Opportunities?



Other Opportunities for Enhanced Thermal Management ?

- **Optimized Micro/Nano Composites for Thermal Interfaces**
- **Package-Integrated Pumped Fluid Cooling Technologies**
- **Engineered Surfaces for Enhanced Heat Transfer (Solid→ Liquid, Liquid→Air)**

There are opportunities for significant performance enhancements throughout thermal systems.

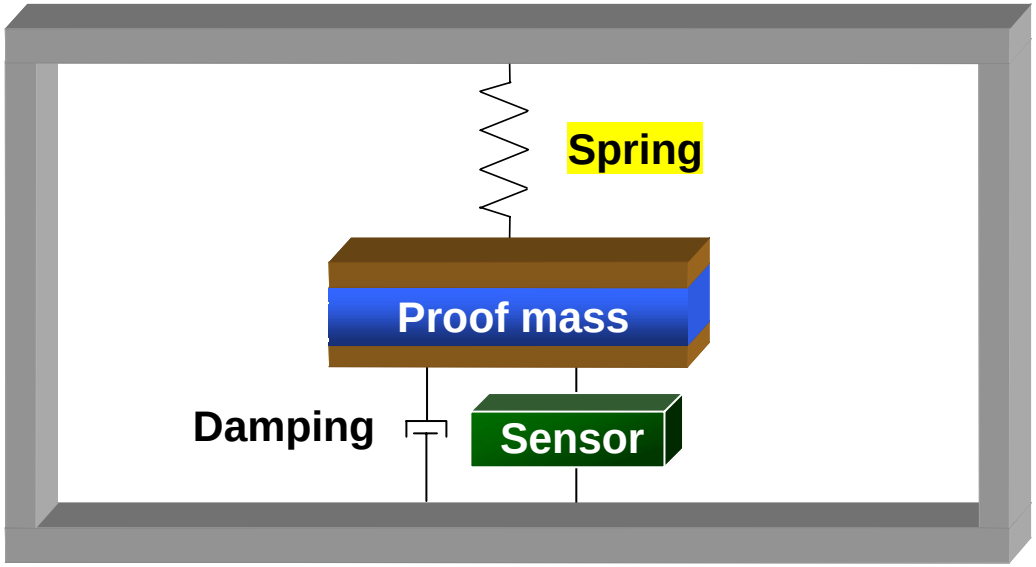
Turning Constants into Variables

Typical Inertial Instrument :

- Fixed Mass
- Fixed Suspension

Performance enhancements achieved through:

- Improvements in sensor
- Accurate temperature compensation
- Expensive packaging



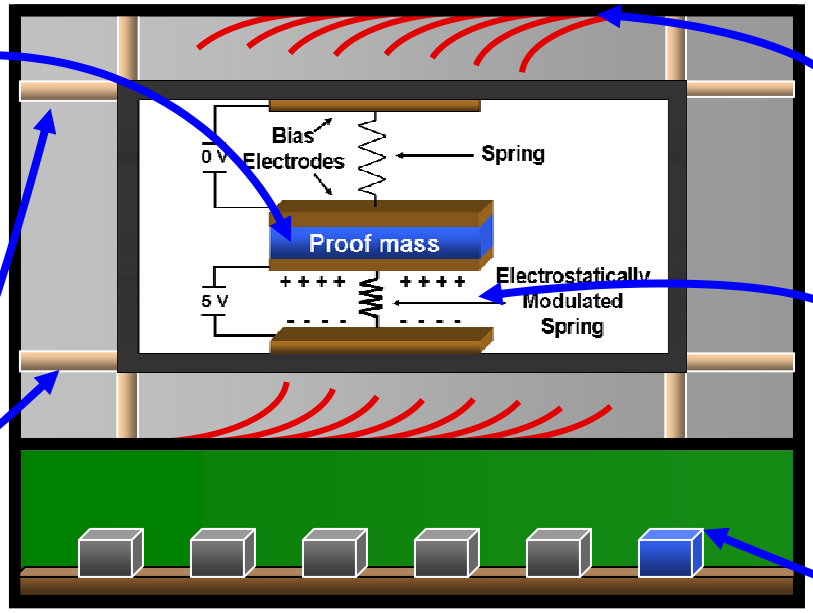
Present Technologies for State of Art Inertial Navigation :

- Mechanical Instruments with Electronics in Package and Temperature Control of System -> fragile, large, high-power, expensive
- All important parameters are static quantities, sensitivity modulation not used
- Advanced nonlinear dynamics, parametric amplification, not used in these systems

Adaptive Mechanical Interfaces

Adjustable Stiffness for Insertion, Q-control
For Adjustment of Sensor for Application, Events

Mechanical Suspension and Thermal Isolation
For miniaturization, low-power, and operation in harsh environments



Variable Thermal Resistors
for passive, zero-power thermal regulation of sensor

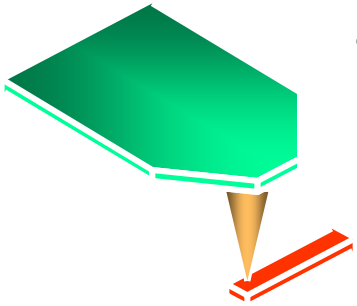
Tuned Dynamics for Parametric Amplification or Internal Chopping
Significant reductions in 1/F noise, drift

Conventional MCM with Thermometer
for secondary temperature Compensation as needed

Opportunities for Improvement through Variable Mechanics :

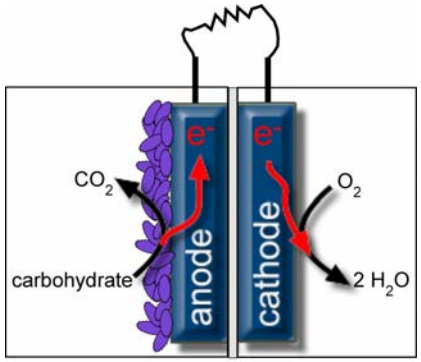
- Utilize nonlinear dynamics to tune performance, amplify, and operate in variable scenario
- Utilize MEMS for device, package, thermal management, dynamic management
- Deliver complete instruments with enhanced performance and smaller size, weight, power,…

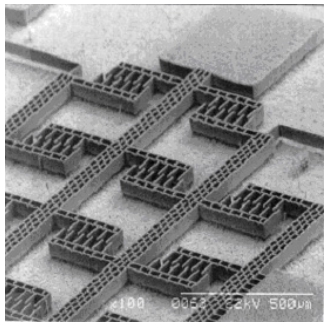
Other Areas of Interest



Tip-Based Nanofabrication
Fields, Fluxes, Gradients that can only exist if confined to nm-scale

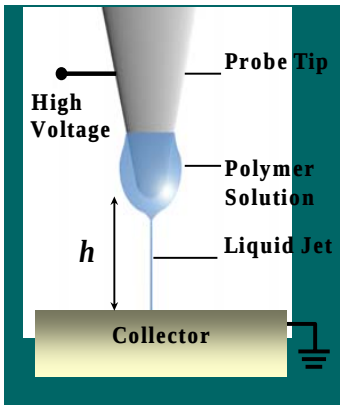
Hand-Held Energy Generation
Convert Cellulose, other available biomaterials into fuel for energy generation





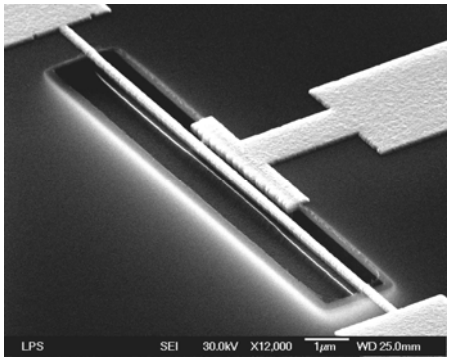
Metal Microstructures
Leverage unique qualities of metals (Titanium, Stainless) for harsh-environment sensing

Neutron Detection
MicroDroplet Chambers and geiger counters for miniature detectors



Electrospun Polymer Fibers
High-strength nm-scale fibers with aligned molecules and nano-composite additives

Quantum Mechanical Detection
Phonon confinement and energy manipulation for sensing, processing



Mechanical Opportunities

Summary

- There are performance-enhancement opportunities on the mechanical side of many systems
- 20+ years of research on MEMS, Nanofabrication, and engineered materials provides many interesting possibilities for impact on thermal and mechanical interfaces
- These situations are ideal opportunities
- Other interests emerging through discussions with labs and users